CHAPTER 2

TEACHING PRACTICES IN MATHEMATICS AND SCIENCE

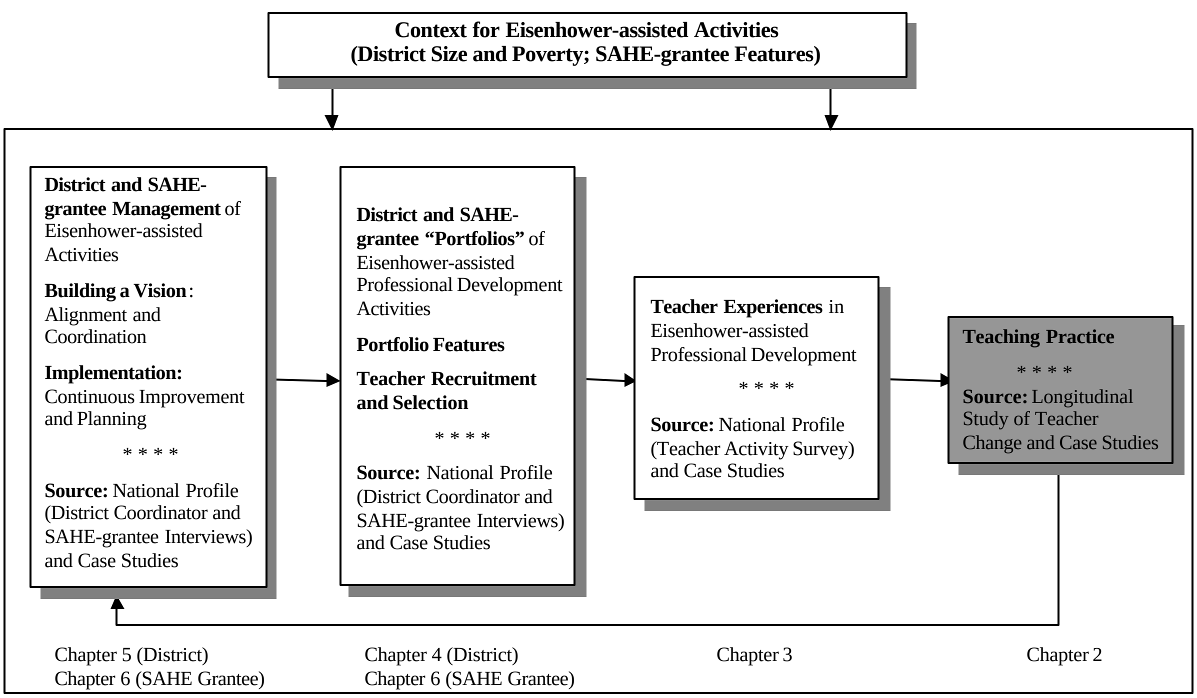
The primary goal of the Eisenhower Professional Development Program is to support professional development experiences for teachers that will enhance classroom teaching and, ultimately, improve student learning. Because improved teaching is critical to improved learning for students, it is a cornerstone of the standards movement. Therefore, this report begins by focusing on classroom teaching practice.

The purpose of this chapter is to lay a foundation for our evaluation of the Eisenhower program, by reviewing the current literature on teaching and learning in mathematics and science and by describing classroom teaching practices in the 30 in-depth case study schools. By drawing on the literature and data on the 30 case schools, we will characterize the strengths and weaknesses of current teaching practices in mathematics and science and identify areas in which further professional development should focus.

The data on classroom practice that we will report come from two sources: the baseline year of our three-year longitudinal survey of teacher change and classroom observations. In a subsequent report, we will use the second and third waves of the longitudinal survey, along with the data reported here, to examine the effects of participation in professional development on changes over time in teaching practice. The data we report in this chapter are thus the first step in our examination of the effect of Eisenhower-assisted activities on teaching practice. Exhibit 2.0 shows how the material covered in this chapter fits into the entire framework of the evaluation.

EXHIBIT 2.0

Conceptual Framework for This Evaluation



Data Sources

This chapter draws on two sources of data collected for the Longitudinal Study of Teacher Change: 1) a baseline survey of teachers in 30 schools and 2) observations of classes for a sample of teachers (two per school) who completed the surveys.[1] In addition, we conducted a content analysis of the National Assessment of Educational Progress, in order to compare the content of instruction that teachers reported in the survey to a national standards for content. In the paragraphs below, we describe each of these sources in turn.

Baseline Wave of the Longitudinal Teacher Survey

To gather data on teachers' classroom teaching practices, we surveyed all teachers who teach mathematics or science in the 30 schools—one elementary, one middle, and one high school in each of the 10 in-depth case study districts. The baseline wave of the survey, which was conducted in the fall of 1997, asked teachers to describe their teaching during the 1996-97 year.[2] In the survey, we asked teachers to select a year-long mathematics or science course to describe. We asked them to choose, if possible, a course they had taught in 1996-97, were continuing to teach in 1997-98, and expected to teach in 1998-99.

The survey contained two main sections concerning teaching practices in the selected course, one on the content taught and one on pedagogy. We discuss these two sections further when we present our results, in subsequent sections of the chapter.

Of the 575 teachers surveyed in the 30 in-depth case schools, 436 teachers (76 percent) responded.[3] Some teachers who responded did not teach mathematics or science during the 1996-97 school year, either because they were not employed as teachers in 1996-97 or because they taught other subjects, and thus they are not included in the analyses of classroom teaching. In addition, we excluded some teachers from particular analyses because they did not complete all of the required items. The sample is 74 percent female and 18 percent minority. Six percent of the teachers in the sample are novice teachers, or teachers who have taught the surveyed subject for two or fewer years. (See Appendix C for a more complete description of the sample and response rates.)

Several features of the sample should be considered in interpreting our results. First, by design, the sample of 30 schools is disproportionately high poverty (50 percent of the sample schools are high poverty, compared to the national average of 25 percent). This feature of the sample is useful in an evaluation of the Eisenhower program, because the program targets teachers in high-poverty schools. Throughout the analyses, we tested whether differences between teachers in high- and low-poverty schools are statistically significant (at the .05 level); we note these findings only when they are significant. Second, we selected the districts and schools in the sample because they had adopted diverse approaches to professional development, in addition to traditional workshops

[1] The other source of teacher-level data collected as part of this evaluation is the teacher activity survey discussed in Chapter 3. In the activity survey, teachers are asked to describe how professional development has changed their instruction. The Longitudinal Study of Teacher Change, on the other hand, will analyze changes in instruction over time to determine the impact of professional development on instruction. Because Longitudinal Study teachers are not judging the impact of professional development themselves, the study minimizes self-report bias.
[2] The remaining two waves ask teachers to describe their teaching in the 1997-98 and 1998-99 years.
[3] The response rate of high school teachers was higher than those of elementary and middle school teachers, in part because principals and department chairs in high school were more involved in administering the survey.

and conferences. If such professional development is more effective than traditional approaches, then the teachers' instruction in the sample schools might be better than that of the average teacher. Finally, the Longitudinal Study of Teacher Change focuses on mathematics and science teachers because they are the primary participants in Eisenhower-assisted activities. For all of these reasons, the sample is not nationally representative, but neither is it extremely unusual.

Classroom Observations

As part of our site visits to the 30 in-depth case study schools, we conducted one-time classroom observations of two teachers in each school—usually one mathematics teacher and one science teacher. In conjunction with the observations, we conducted a brief pre-observation interview and a somewhat longer post-observation interview with each of the 60 teachers we observed. The teachers we observed were selected by the principals of the schools we visited, in part based on their availability at the time of our visit and willingness to be observed; participation in professional development was not a factor in selecting teachers to observe. Thus, the teachers we observed are not necessarily representative of all teachers in the study schools.

We conducted the observations using a structured protocol, designed in part to parallel our teacher survey instrument. Prior to conducting the observations, we conducted a training session in which our site visitors observed videotaped lessons and coded them using our observation protocol. This allowed the site visitors to develop a common understanding of the protocol and to check inter-rater reliability.

National Assessment of Educational Progress (NAEP)

To report on the consistency of the content taught with high standards, we needed to identify an appropriate measure of high standards. The National Council of Teachers of Mathematics (NCTM) and National Research Council (NRC) standards set a framework for important mathematics and science concepts that should be taught in the classroom. However, these standards are at a level of generality that makes quantitive content analysis difficult; therefore, we look to the National Assessment of Educational Progress (NAEP) to make explicit the content focus of the standards. The NAEP provides items that reflect this framework and permit content analyses items to determine relative emphases for mathematics and science content. In order to develop a test that would be perceived as national, the National Center for Education Statistics has modeled the NAEP on the professional associations' standards (Reese et al., 1997). For example, 30 percent of the science assessment involves hands-on performance exercises and 50 percent involves open-ended questions (NAGB, 1997); these also are areas of emphasis for the standards. The high standards set by the test are evident in the scores reported for the 1996 science assessment; only three percent of students tested at the advanced level and 21 to 29 percent tested at or above the proficient level (Raizen, 1998). As "the nation's report card," the NAEP represents an appropriate standard, although admittedly not the only possible standard. Because the NAEP focuses on content and performance goals consistent with standards developed by national professional associations, and because the

NAEP establishes high expectations for achievement, it is reasonable to use the items on the NAEP tests as a measure of high instructional standards.[4,5]

Organization of Chapter

The rest of the chapter is organized in four sections. The first section reviews current standards and literature on effective content and pedagogy. The second section describes the content of instruction in the 30 in-depth schools, drawing on data from the baseline wave of the longitudinal survey and the classroom observations. The third section focuses on pedagogy in the 30 schools. Finally, in a brief concluding section, we draw together the implications of our analysis of teaching in the 30 schools.

EFFECTIVE CONTENT AND PEDAGOGY

An understanding of good mathematics and science instruction begins with a vision for the classroom. This is a difficult vision to capture for two reasons. First, effective learning experiences differ; there is no single model of an ideal class. Second, educators and researchers do not know all there is to know about ideal instructional strategies. However, research has identified some common elements of "good instruction" in mathematics and science. In particular, certain elements of content and pedagogy improve student learning.

Overall, effective instruction can be characterized by *content* that is aligned with high standards and *pedagogy* focused on active learning. Content includes both the topics of instruction, such as fractions, and the teacher's expectations for student performance, such as memorizing or understanding concepts. Pedagogy refers to the types of activities used in instruction and typically includes dimensions such as whole class versus individual instruction or project versus text-based instruction.

Content

Content coverage matters for student learning. Student achievement improves when the content of instruction is consistent with national standards and assessments (Cohen & Hill, 1998; Gamoran et al., 1997). National standards for mathematics and science specify critical content areas that effective instruction should address: covering core topics, such as life science, and developing students' topic understanding in sophisticated ways, such as making connections to real-world situations.

[4] However, some performance goals for students—such as carrying out sustained work—cannot be adequately measured by a timed, paper-and-pencil test such as the NAEP.

[5] Mathematics and science generally are tested in every other NAEP administration, or every four years. The data used for these analyses were the 1996 mathematics and science NAEP tests. See Appendix D for a description of the NAEP content analysis.

The National Council of Teachers of Mathematics (NCTM) developed standards for mathematics curricula (NCTM, 1989) and instruction (NCTM, 1991).[6] The key content areas differ by school level (i.e., K-4, 5-8, 9-12), but generally focus on the following:

- Numbers and operations: understanding and representing numbers and relationships, understanding operations, and using computational tools and strategies.

- Patterns and functions: understanding types of patterns and relationships, using symbolic forms, and using models.

- Algebra: understanding basic concepts (e.g., variable, expression); representing situations with tables, graphs, rules, and equations; analyzing tables and graphs; solving linear equations; investigating inequalities; and applying algebraic methods to solve real-world problems.

- Geometry and spatial sense: analyzing two- and three-dimensional objects, using different representational systems, recognizing the usefulness of transformations, and using visualization and spatial reasoning.

- Measurement: understanding attributes, units, and systems of measurement, and applying a variety of techniques, tools, and formulas.

- Statistics and probability: posing questions and using data to answer them, interpreting data, developing and evaluating inferences, and understanding and using notions of chance.

The mathematics standards also identify standards for student performance that apply across all grades:

- Problem solving: building new knowledge through work with problems, developing a tendency to use problem-solving skills within and outside mathematics, using and adapting varied strategies to solve problems, and reflecting on mathematical thinking.

- Reasoning: recognizing reasoning and proof as important, making and investigating mathematical conjectures, developing and evaluating mathematical arguments, and using various types of reasoning.

- Making connections: connecting different mathematical ideas, understanding how ideas build to form a coherent whole, and using mathematics in non-mathematical contexts.

- Communicating: organizing mathematical thinking to communicate with others, expressing mathematical ideas coherently, considering the thinking of others, and using the language of mathematics.

[6] A draft of the revised 1989 standards was released in 1998. Major changes include: 1) reorganizing the grade-level breakdown from K-4, 5-8, and 9-12 to preK-2, 3-5, 6-8, and 9-12; 2) relating process standards—expectations for student performance—more closely to content standards; 3) adding the process standards of representation; and 4) emphasizing the development of content strands (e.g., algebra) over the grade levels (Romberg, 1998).

Reform in science education has emphasized real-world problems, investigations of natural phenomena, and linkages to other subjects rather than abstract knowledge (Raizen, 1998). In setting content standards for science, the National Research Council (NRC) identified certain content areas as central to teaching and learning science:[7]

- Physical, life, earth and space science: knowing, understanding, and using knowledge of matter, motion and forces, energy, atoms, chemical reactions, organisms, cells, evolution, behavior, earth systems, and the universe.

- Science and technology: developing abilities of technological design and understanding about science and technology.

- Science in personal and social perspectives: understanding and making decisions on personal and community health, populations, resources, the environment, and science in society.

- History and nature of science: understanding the nature of science from a historic perspective.

In addition, NRC identified some concepts and student performance standards that cross content areas, such as systems, order, and organization; evolution and equilibrium; and understanding of and ability to conduct scientific inquiry.

In setting standards for student performance, the NRC emphasized developing skills to do scientific inquiry, such as asking questions, collecting data, and developing explanations. An underlying premise of these standards is to focus less on "student acquisition of information" and more on "student understanding and use of scientific knowledge, ideas, and inquiry processes" (NRC, 1996: p. 52). Thus, the performance goal of memorizing material is less central than the goals of understanding concepts or making connections.

As the standards imply, the organization of the curriculum within the school also affects students' learning experiences. Past research has suggested that there is too much redundancy in content from one grade level to the next, at least for kindergarten through eighth grade. Compared to other countries, the curriculum in the U.S. covers more topics; each year the curriculum expands to incorporate new topics but, unlike the practice in other countries, topics are not phased out of the curriculum in successive grades (Schmidt, McNight, and Raizen, 1997). Effective instruction entails organizing the curriculum so that learning at each grade builds on prior learning, developing deeper and more complex understandings.

Pedagogy

Pedagogy—or the way content is presented—also matters for student learning. National mathematics and science standards emphasize the pedagogical approach of active instruction. For example, the science standards advocate inquiry-based learning, in which the teacher facilitates

[7] The National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and NRC each developed standards documents (see AAAS, 1993; AAAS, 1989; NSTA, 1992). The three organizations agreed that NRC would be responsible for developing broad standards for science, so the NRC standards are the primary focus here (Raizen, 1998).

rather than informs (NRC, 1996). The mathematics standards stress instruction that builds on students' experience, in which students are actively engaged in wrestling with complex problems (NCTM, 1998).

The standards are based on research that indicates that active learning is especially effective. Students learn science best when they are active participants, engaged in activities, rather than passive recipients of lecture-style instruction (Raizen, 1998). Active learning calls for students to be involved in creating their own learning experiences. Pedagogical approaches that support active mathematics and science learning include using inquiry-based instruction, in which the teacher facilitates rather than informs, actively engaging students in complex problems for which there are no simple solutions, and incorporating multiple disciplines in activities (NCTM, 1998; NRC, 1996; Raizen, 1998).

National standards in mathematics and science, consistent with research on effective instruction, indicate that both content—especially core topics and complex performance goals—and pedagogy—especially active learning—are important to student learning. Clearly, content and pedagogy are interrelated. While active learning is especially student-driven, it is still coordinated around content—effective teachers set instructional goals and monitor activities, intervening when appropriate. Thus, while we examine content and pedagogy in turn in this chapter, the two together contribute to effective instruction.

CONTENT COVERAGE AND HIGH STANDARDS

Section Findings

- *Teachers tend to give more emphasis to low-level topics (e.g., number sense, calculation) than do items on the National Assessment of Educational Progress (NAEP) and less emphasis to topics such as geometry; further, there is much redundancy in topics covered from grade to grade.*

- *Teachers report balancing their emphases across all six goals for student performance, while the NAEP focuses more on some of the concrete performance goals. Although this suggests that teachers are emphasizing more abstract performance goals, such as understanding concepts rather than memorizing, our observations suggest that these performance goals are not as deep as teachers report them to be.*

- *Teachers cover content areas in greater breadth and less depth than the content assessed by the NAEP, especially in high-poverty schools.*

- *Mathematics instruction is more highly aligned with items on the NAEP than is science instruction, and elementary and middle school instruction are more highly aligned than is high school instruction.*

In this section, we examine whether the content covered by teachers in our sample emphasizes high standards. We begin our discussion by describing our data on the content taught and the approach we have taken to determine the degree to which the content reflects high standards. Then, we turn to our results.

Content and Alignment with Standards

To assess the consistency of the content taught with national standards, we have collected unusually fine-grained information on the content covered by our sample of teachers, and we have developed a unique strategy of measuring alignment, drawing on the full set of items administered as part of the National Assessment of Educational Progress. In the following sections, we provide a brief overview of these methods. (See Appendix C for more detail.)

Measuring the Content Taught

Our main data on content come from the baseline wave of the longitudinal survey of teacher change. We characterize the content taught in terms of two major dimensions: the *topics* covered and the *performance goals* teachers hold for students.

In the content section of the survey, we asked teachers to describe the content they taught in the class they chose to describe, using a two-dimensional matrix. (Different forms of the matrix were used for elementary, middle, and high school mathematics and science. See Exhibit 2.1 for a sample section from the elementary mathematics form of the survey.) The matrix was initially developed by Porter et al. (1993) in a comprehensive study of mathematics reform and was revised for purposes of the Eisenhower evaluation. Since then, the matrix has been used in several other studies, including Gamoran et al. (1997).[8]

The rows of the matrix contain a comprehensive list of the topics and subtopics teachers might cover. Algebra, for example, is a topic in mathematics, and multi-step equations is a subtopic under algebra. Astronomy is a topic within science, and the Earth's moon is a subtopic under astronomy. Each subject area (i.e., mathematics and science) and each school level (i.e., elementary, middle, and high school) has a unique set of topics and subtopics. The matrix for middle school mathematics, for example, has nine topics and 84 subtopics, while the matrix for high school science has 28 topics and 191 subtopics.

The columns of the matrix contain performance goals for students. Performance goals are teachers' expectations for what students should be able to do. There are six performance goals in the matrix: 1) memorize; 2) understand concepts; 3) perform procedures; 4) generate hypotheses; 5) collect, analyze, and interpret data; and 6) make connections. (See Exhibit 2.2 for definitions of the performance goals.) For example, when a teacher emphasizes memorizing, the teacher may expect students to be able to produce definitions or terms, facts, and formulas from memory. When a teacher emphasizes using information to make connections, the teacher may expect students to be able to use and integrate concepts, apply ideas to real-world situations, build or revise theory, and make generalizations.

[8] Porter et al. (1993) present comprehensive information on the reliability and validity of data collected using the content matrix, as well as using teacher logs and classroom observations.

EXHIBIT 2.1

Excerpt from Content Coverage Section of the Elementary School Mathematics Teachers Survey

Elementary School Topics	*Coverage*	*Your Performance Goals for Students*					
Whole Numbers	**<none>**	Memorize	Understand Concepts	Perform Procedures	Generate Hypotheses	Collect Analyze/ Interpret	Make Connections
Addition	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Subtraction	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Multiplication	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Division	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Combinations of add, subtract, multiply, and divide	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Equations (including missing addend, factor, etc.)	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Fractions	**<none>**	Memorize	Understand Concepts	Perform Procedures	Generate Hypotheses	Collect Analyze/ Interpret	Make Connections
Identify equivalent fractions	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Add	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Subtract	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Multiply	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Divide	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
Combinations of add, subtract, multiply, and divide	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3

Source: Longitudinal Teacher Survey Elementary School Mathematics, Fall 1997 (1996-97 school year).
How to read this exhibit: The rows represent topics (in bold typeface) and their corresponding subtopics. The teachers were asked to complete the grid by 1) indicating whether the topic had not been covered during the school year by circling “none”; 2) noting the level of coverage for each subtopic by circling 0, 1, 2, or 3 to indicate not covered to sustained coverage; and 3) marking the emphasis for each subtopic on each of the performance goals by circling 0, 1, 2, or 3 to indicate no emphasis to sustained emphasis.

EXHIBIT 2.2

Performance Goals for Students

The following are various performance goals that teachers hold for their students. Refer to this list in describing your performance goals for each topic covered as part of instruction.

Memorize
- Definitions/Terms
- Facts
- Formulas

Understand Concepts
- Explain concepts
- Explain procedures/methods of science & inquiry
- Develop schema, or frameworks of understanding
- Represent concepts with manipulatives or models

Perform Procedures
- Use numbers
- Do computation, execute procedures or algorithms
- Replicate (illustrative or verification) experiments
- Follow procedures/instructions

Generate Questions/Hypotheses
- Brainstorm
- Design experiments
- Solve novel/non-routine problems

Collect, Analyze & Interpret Data
- Make observations
- Take measurements
- Classify/order/compare data
- Analyze data, recognize patterns
- Infer from data, predict
- Explain findings, results
- Organize & display data in tables, graphs or charts

Use Information to Make Connections
- Use & integrate concepts
- Apply to real-world situations
- Build/revise theory
- Make generalizations

Source: Longitudinal Teacher Survey, Instruction booklet for section II.
How to read this exhibit: This exhibit illustrates the instructions given survey respondents for completing the matrix displayed in Exhibit 2.1.

A *content area* can be defined as the intersection of the two dimensions, topics and performance goals. For example, if teachers emphasize memorizing facts about the Earth's moon, the content area incorporates the subtopic (the Earth's moon) and the performance goal (memorizing). Both elements—topics and performance goals—are integral to understanding the content of a lesson or course. For example, the student learning that would be likely to take place if the content were memorizing facts about the Earth's moon (e.g., gravity, distance from the Earth) is very different from the student learning that would occur if the content were understanding the Earth's moon (e.g., forces working to keep satellites in orbit).

Each teacher was asked to follow several steps in describing the teacher's year-long course using the matrix. First, the teacher indicated the amount of time given to each subtopic, using a scale from 0=no time through 3=more than two lessons or class periods. Then, the teacher indicated the relative amount of emphasis given to each performance goal when teaching the subtopic, using a scale from 0=no emphasis to 3=sustained emphasis. We used the full matrix of data provided by each teacher to calculate the percentage of the teacher's total year-long class time devoted to each topic and subtopic, each performance goal, and each content area (intersection of a subtopic and performance goal).

Assessing the Consistency with High Standards

We compare teachers' instruction to the NAEP items in order to assess how well instruction meets high standards. To determine the relative amount of emphasis given by the NAEP to each subtopic, performance goal, and content area in our elementary, middle, and high school science and mathematics matrices, we reviewed the full set of NAEP mathematics and science items for the 1996 tests for fourth, eighth, and twelfth grade.[9] We asked two curriculum experts in mathematics and two experts in science to review each NAEP item and to determine the specific subtopics and performance goals each item was designed to tap.[10] Using this information for the full set of NAEP items, we computed the relative emphasis given by NAEP to each subtopic, performance goal, and content area.

In the paragraphs that follow, we draw on our data provided by teachers, as well as our information from the NAEP, to examine four aspects of the content taught. First, we examine the extent to which the topics covered by the teachers in our sample match the topics assessed by the NAEP. Then, we consider the extent to which the performance goals our teachers emphasize match the NAEP. Third, we examine the content areas (intersection of topics and performance goals). Finally, we develop an overall index of the alignment between the content covered by teachers and the content assessed by the NAEP.

Topic Emphases and High Standards

In this section, we examine the emphasis given by teachers in our sample to specific topics, and we compare this with the relative emphasis given to the same topics in the NAEP. Research indicates that some topics, for example geometry and measurement in mathematics, are special weaknesses for students in the United States (Beaton et al., 1996). In the Third International Mathematics and Science Study, U.S. students in seventh grade scored 19th out of 27 countries in geometry and 23rd in measurement. U.S. students in eighth grade scored 21st out of 25 countries in geometry and 23rd in measurement (Beaton et al., 1996). Thus, in interpreting our results, we give special attention to these two topics.

Exhibit 2.3 presents our data on the emphasis given to particular topic areas, for the middle school mathematics teachers in our sample. (Similar results for the other teachers in our sample are included in Appendix D.) The results indicate that topics that traditionally have been weaknesses for U.S. students, especially for mathematics, do not receive much attention from teachers in our sample. Despite evidence that middle school students need to focus on measurement and geometry, middle school teachers surveyed for this study taught measurement on average for 12 percent of their course, compared to the NAEP's emphasis of 20 percent. The average middle school teacher taught geometry for nine percent of their course, compared to the NAEP's emphasis of 15 percent. On the other hand, middle school teachers tend to give more emphasis to low-level topics than does the NAEP. For example, middle school teachers emphasized number sense 37 percent of the time compared to 14 percent for the eighth-grade NAEP.[11]

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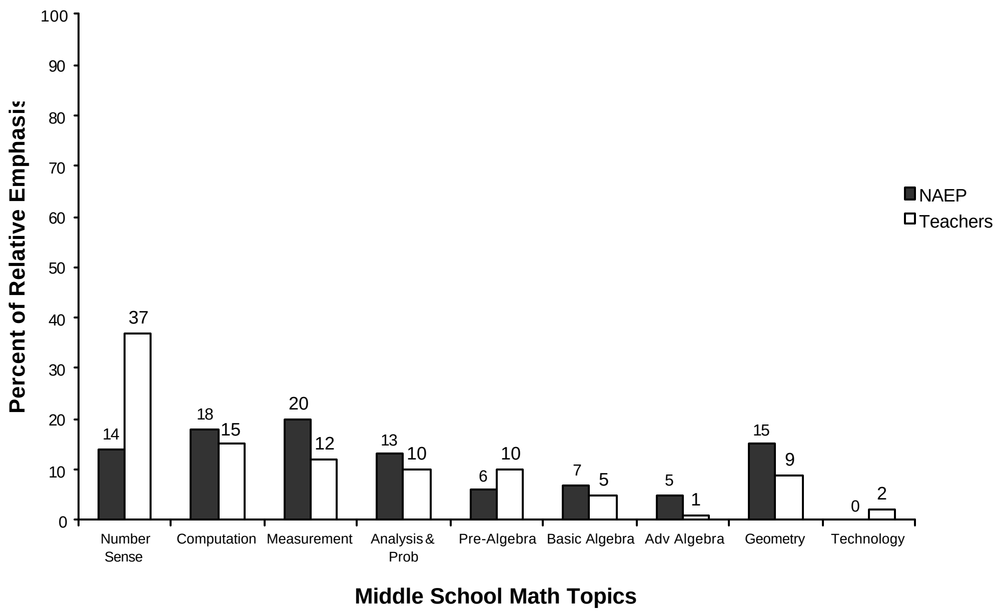
[9] The NAEP fourth-grade test was compared to instruction for teachers in elementary school (grades K-5). The NAEP eighth-grade test was compared to instruction for teachers in middle school (grades 6-8). The NAEP twelfth-grade test was compared to instruction for teachers in high schools (grades 9-12).

[10] Appendix D provides information on the reliability of the expert ratings of the NAEP items.

[11] Results shown in Appendix D indicate that the emphasis on geometry is lower in high-poverty schools than in low-poverty schools.

EXHIBIT 2.3

Percentage of Emphasis on Topics in Middle School Math, Reported by NAEP and by Teachers in the Longitudinal Teacher Survey (n=38)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first bar shows that NAEP has a relative emphasis of 14 percent on the topic Number Sense for middle school math, and the second bar shows that middle school math teachers in our sample indicate a relative emphasis of 37 percent on the topic Number Sense. Each of the topic areas for middle school math is included in the bar chart. The relative emphasis can be between 0 and 100 percent.

Questions about the topic focus for instruction can be extended from whether teachers cover critical topics to whether they cover any topics. Previous research has found that teachers sometimes focus so much on changing the process of instruction that they neglect the topics of the lesson. Roitman (1998), for example, described a case in which an observed teacher was so focused on active learning activities that her lesson was topic-free. To consider this possibility, using the Eisenhower data, we turn to the classroom observations.[12] Several of the observed lessons did focus on process to the point of having little or no content emphasis. For example, in a sixth-grade science lesson in Boonetown, the class focused on using the scientific method. Students conducted an experiment to test the absorption of different brands of paper towels, as part of a consumer unit. In preparation for the experiment, student groups had written hypotheses and experimental designs the day before. The teacher introduced the class, reviewed relevant vocabulary, and directed the students to work in groups. The groups designed and conducted their own experiments. At the end of the lesson, the teacher asked students to consider ways in which the experiment could be improved. However, students did not discuss or present their findings. While the lesson could have developed

[12] The surveys, which required teachers to report content foci, cannot be used to answer this question. If the teacher did not report on content, the survey was considered incomplete, and the data were not used.

understanding of material composition or properties, the focus throughout was on process rather than content.

The United States differs from other countries in how the content is organized across grades. In the U.S., topics are repeated in many grades, theoretically with increasingly complex subtopics. Other countries, such as France and Japan, focus on selected topics at each grade level (Matheson et al., 1996). For example, the eighth-grade mathematics teachers in Japan focus on four topics, with relatively little emphasis (less than four percent of instructional time) on other topics. In contrast, U.S. teachers spread instruction over 21 topics (Wilson and Blank, 1999).

According to national standards for science and mathematics, developed by the National Research Council (NRC) and the National Council of Teachers of Mathematics (NCTM), it is possible to cover the same broad topics across grades, while enhancing the depth of exposure. Revisiting topics in successive grades should build on understanding, allowing instruction to focus on more complex subtopics within broad topics.

The NRC science content standards cover the same broad topics (i.e., physical, life, earth and space science, science and technology, science in personal and social perspectives, and history and nature of science) at all grade levels. These standards stress developing a more sophisticated understanding of more advanced subtopics within each topic as students move up grade levels, to reflect developmental and learning abilities of students. With this approach, the subtopics become more abstract and students are expected to develop greater conceptual understanding as they progress through the grades. Thus, NRC's science standards suggest that, at a gross level, there should be substantial overlap in topics across grade levels; however, students at each school level should be learning different subtopics within these broad topics.

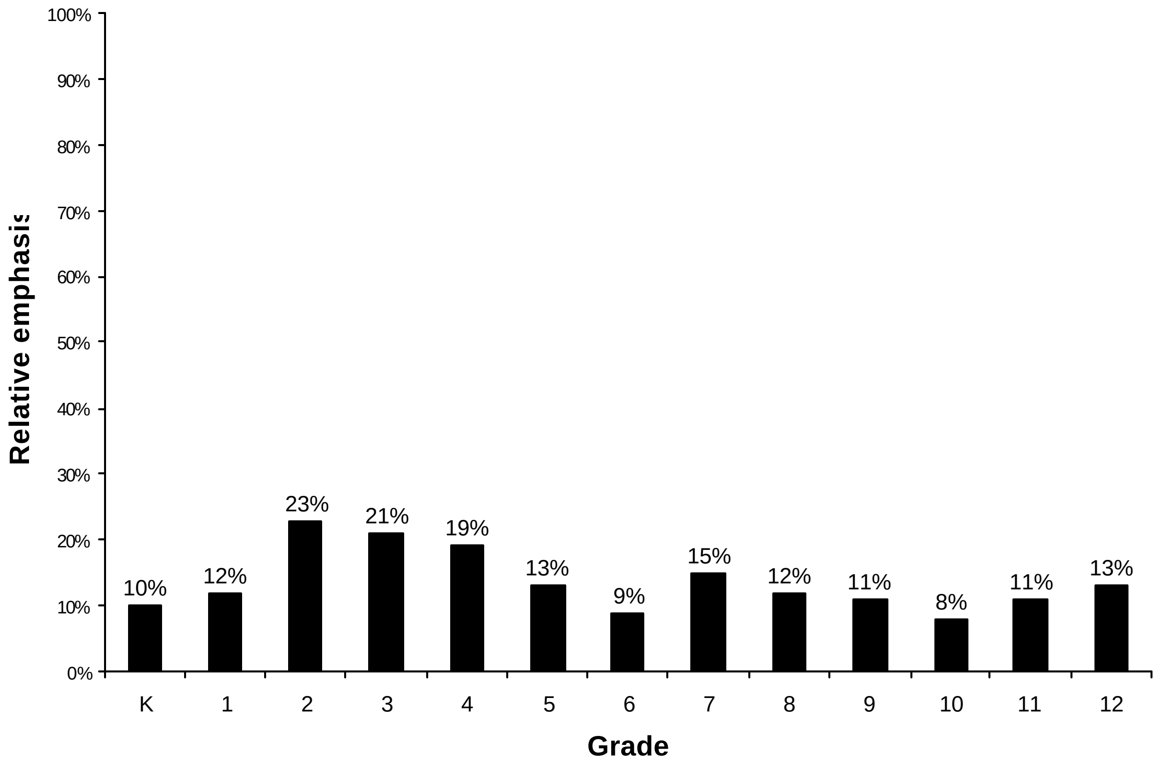
Similar to the science standards, the NCTM standards emphasize five major topics (i.e., number and operations; patterns, functions, and algebra; geometry and spatial sense; measurement; and data analysis, statistics, and probability) in every grade. Again, like the science standards, the mathematics standards stress that specific subtopics within broad topics become more sophisticated as the student progresses through the grades.

Consistent with the international research, our data show that, on average, teachers across grades generally teach the same topics. There is little clear pattern of intensified coverage in broad topic areas as grade levels increase. For example, teachers at all grade levels teach measurement in mathematics, some grades more than others, but there is no pattern of consistent increase or decrease in focus on measurement as grade levels increase (see Exhibit 2.4). First-grade mathematics teachers emphasized measurement for 12 percent of the time, second-grade teachers for 23 percent, sixth-grade for 9 percent, and twelfth-grade for 13 percent.

Furthermore, the measurement subtopics emphasized do not consistently increase in complexity as the grade level increases (see Exhibit 2.5). Of the 16 measurement subtopics, only four show the expected pattern. Two of the more low-level subtopics (i.e., use of instruments and time and temperature) showed, on average, decreased emphasis as grade level increased (from 34 percent to nine percent and from 23 percent to one percent, respectively). Two of the more complex topics (i.e., Pythagorean theory and trigonometry) showed, on average, increased emphasis as the grade level increased (from zero to 6 percent and from zero to 48 percent, respectively). For the most part, however, there is little evidence of increasingly complex topics in successive grades.

EXHIBIT 2.4

Percentage of Emphasis Mathematics Teachers in the Longitudinal Teacher Survey Give to Measurement, by Grade (n=181)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first bar shows that kindergarten teachers in the longitudinal teacher survey report a 10 percent emphasis on measurement. Each bar and the number on top of it represent the percent of emphasis given to measurement for teachers in each grade.

EXHIBIT 2.5

Relative Emphasis on Subtopics in Measurement by Grade, as Reported by Teachers in the Longitudinal Teacher Survey (n=181)

	K	1	2	3	4	5	6	7	8	9	10	11	12	Trend
Use of instruments	33.6	20.0	8.0	20.4	23.1	23.2	12.8	9.7	6.6	7.6	3.6	3.6	9.4	Decrease
Conversions	1.5	0.5	0.6	2.2	5.9	5.6	8.5	7.9	9.0	4.1	4.9	2.8	2.9	None
Metric system	0	11.7	1.9	7.3	5.5	9.4	12.1	11.6	5.9	4.0	2.9	2.0	1.2	None
Length, perimeter	9.6	7.6	4.8	9.5	10.1	12.9	15.7	17.4	12.2	16.2	7.6	9.1	6.4	None
Area, volume	4.3	3.0	1.8	9.3	11.9	11.3	14.7	11.1	12.6	14.7	10.0	8.6	4.3	None
Telling time	18.1	31.3	30.9	18.9	15.9	7.3	na	na	na	na	na	na	na	None
Non-decimal money	2.7	12.8	35.3	11.9	6.2	8.7	na	na	na	na	na	na	na	None
Circles	1.7	1.4	1.2	0.6	3.9	7.2	8.6	9.7	13.6	10.6	6.8	5.8	7.0	None
Mass	5.5	4.0	2.1	4.2	6.7	5.8	4.4	3.9	3.4	2.6	2.7	1.2	0.7	None
Time, temperature	22.6	7.7	13.3	15.6	10.1	8.8	9.0	3.7	4.8	2.9	2.7	3.8	1.1	Decrease
Theory	na	na	na	na	na	na	2.3	2.6	1.6	2.2	1.9	1.2	0.6	None
Surface area	na	na	na	na	na	na	3.3	9.0	8.2	4.7	7.3	2.9	5.1	None
Angles	na	na	na	na	na	na	7.1	8.3	6.9	9.5	5.6	8.2	5.1	None
Pythagorean theory	na	na	na	na	na	na	0	2.7	10.0	9.7	7.2	6.8	6.4	Increase
Simple trig, right triangles	na	na	na	na	na	na	0	0.3	1.6	7.5	31.0	38.3	47.8	Increase
Speed	na	na	na	na	na	na	1.4	2.1	3.6	3.7	5.9	5.7	2.2	None

Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first cell shows that Kindergarten teachers place 33.6 percent of topic emphasis on Use of Instruments. Use of Instruments received 20 percent of the relative emphasis by 1st-grade teachers, 8 percent by 2nd-grade teachers, 20.4 percent by 3rd-grade teachers, 23.1 percent by 4th-grade teachers, 23.2 percent by 5th-grade teachers, 12.8 percent by 6th-grade teachers, 9.7 percent by 7th-grade teachers, 6.6 percent by 8th-grade teachers, 7.6 percent by 9th-grade teachers, 3.6 percent by 10th-grade teachers, 3.6 percent by 11th-grade teachers, and 9.4 percent by 12th-grade teachers. Overall, there was a decreasing trend in the relative emphasis on Use of Instruments by teachers as the grade level increases.

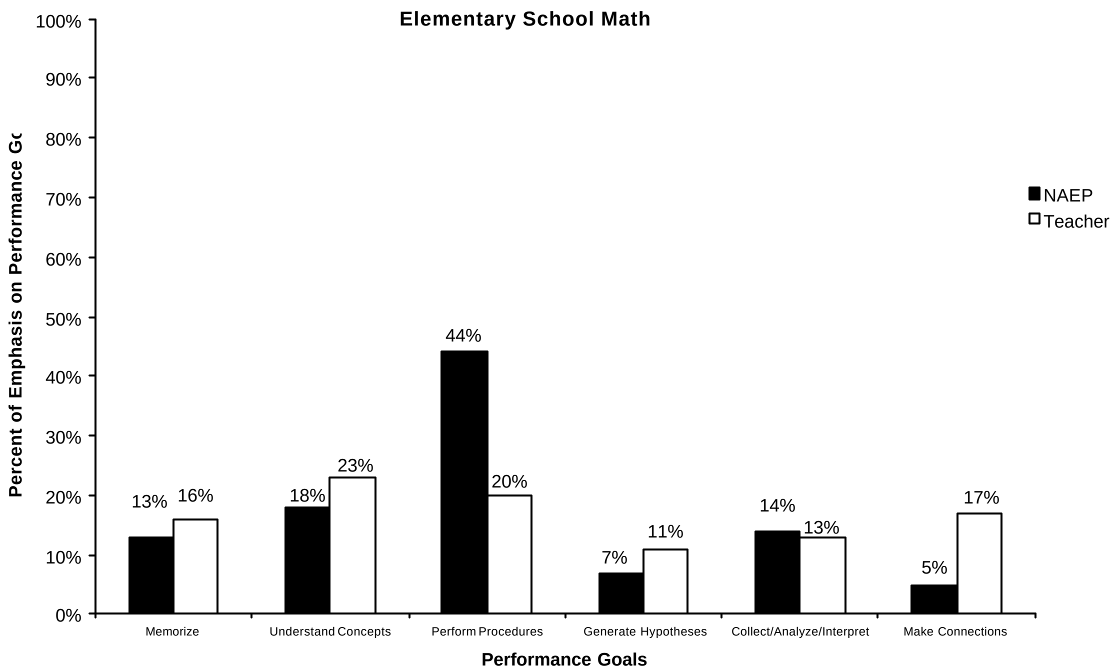
Performance Goals and High Standards

In this section, we compare the performance goals emphasized by teachers in our sample with the performance goals emphasized in the NAEP. Prompted in part by the report *A Nation at Risk* (NCEE, 1983), there has been a movement toward teaching for understanding rather than memorizing (Roitman, 1998). National mathematics and science standards emphasize teaching for understanding. Teaching for understanding and teaching for memorizing are *performance goals*, or expectations teachers have for what students should be able to do. Ideally, teachers would have performance goals for students that are consistent with the performance goals advocated in the national standards. Of the six performance goals teachers could identify on the Longitudinal Teacher Survey (i.e., memorize, understand concepts, perform procedures, generate hypotheses, collect/analyze/interpret data, make connections), four are especially relevant for the abstract thinking involved in developing complex understanding: understanding concepts, generating hypotheses, collecting/analyzing/interpreting data, and making connections. Of the six performance goals, two are especially relevant for developing concrete skills and knowledge: memorizing and performing procedures. Ideally, teachers will balance their emphasis on the six performance goals. In this section, we examine whether teachers have balanced performance goals for their students, comparing teachers' performance goals to the emphases on the NAEP.

Exhibit 2.6 presents our results for elementary school mathematics. (Results for other teachers in our sample appear in Appendix D.) The results indicate that NAEP items tend to focus on the performance goals that involve less abstract thinking, such as memorizing, which does not exemplify the ideal pattern advocated by the national standards. Compared to the performance goal emphases in the NAEP, teachers in our sample give more equal emphases to all six goals. For example, elementary mathematics teachers report devoting 20 percent of their class time to performing procedures, compared to 44 percent for the NAEP, and they devote 17 percent of their class time to making connections, compared to 5 percent for the NAEP.

EXHIBIT 2.6

Comparison of NAEP and Teachers in the Longitudinal Teacher Survey on Emphasis on Performance Goals (n=74)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first bar shows that the NAEP has a relative emphasis of 13 percent on the performance goal Memorize, and the second bar shows that teachers in our sample indicate a relative emphasis of 16 percent on the performance goal Memorize. Each performance goal is included in the bar chart. The relative emphasis can be between 0 and 100 percent.

To examine differences across types of teachers in the emphasis given to the six performance goals, we computed the mean percent emphasis for each goal by school level (elementary, middle, and high school), subject (mathematics and science), and school poverty (high and low). Results indicate that mathematics teachers emphasize the more concrete performance goal, performing procedures, significantly more than science teachers do, while science teachers emphasize the more abstract performance goals—collecting, analyzing, and interpreting data, making connections, and generating hypotheses—significantly more than mathematics teachers do. Teachers in high-poverty schools place significantly greater emphasis on memorizing and significantly less emphasis on understanding concepts, compared to teachers in low-poverty schools. High school teachers place significantly greater emphasis on performing procedures than either elementary or middle school teachers, and significantly less emphasis on generating hypotheses than middle school teachers; this reinforces the finding noted earlier, that instruction does not seem to be more complex or abstract at higher grade levels (see Exhibit 2.7).

EXHIBIT 2.7

Mean Percent Emphasis Given to Each Performance Goal (Standard Deviation), by School Level, Subject, and Poverty Level (n=355)

	Memorize	Understand Concepts	Perform Procedures	Generate Hypothesis	Collect/ Analyze/ Interpret	Make Connections
School Level						
Elementary	15.74 (0.07)	23.94 (0.12)	18.19 (0.06)	11.72 (0.06)	13.07 (0.05)	17.22 (0.05)
Middle	15.55 (0.08)	21.84 (0.05)	18.32 (0.05)	12.63 (0.05)	13.98 (0.06)	17.65 (0.05)
High	15.59 (0.06)	23.47 (0.07)	20.37 (0.07)	10.81 (0.05)	12.97 (0.06)	16.78 (0.06)
Subject						
Mathematics	15.76 (0.06)	23.15 (0.07)	22.18 (0.06)	10.66 (0.06)	11.70 (0.06)	16.46 (0.05)
Science	15.51 (0.08)	23.45 (0.11)	15.75 (0.04)	12.54 (0.05)	14.84 (0.05)	17.87 (0.05)
Poverty Level						
High Poverty	16.60 (0.07)	21.75 (0.07)	18.06 (0.05)	12.46 (0.05)	13.86 (0.05)	17.17 (0.05)
Low Poverty	15.09 (0.06)	24.18 (0.10)	19.59 (0.07)	11.09 (0.06)	12.88 (0.06)	17.14 (0.06)

Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The group of three cells at the upper left of the table (the means for memorize by school level) shows that there is not a significant difference in the emphasis on memorization between elementary, middle, and high school teachers. The table should be read by columns, focusing on each performance goal separately.
Note: The arrows indicate significant differences between groups (p<05), with the head of the arrow showing the direction of the difference.

The emphases teachers in this study give to the six performance goals found in this study are inconsistent with previous studies of teachers' instructional emphases. In the early 1980s, studies of 41 elementary school teachers found that 70 to 75 percent of mathematics instruction focused on teaching students skills, such as addition, with little attention to developing conceptual understanding or problem solving (Porter, 1989). In a groundbreaking study of mathematics and science instruction in high school, Porter et al. (1993) found that in 1990 and 1991, teachers reported focusing most on solving routine problems (e.g., computation), in both mathematics and science. The performance goal of building and revising theory and developing proofs was emphasized very little. Observations confirmed that teachers did, in general, focus on the more rote performance goals such as memorizing facts, definitions, and equations, performing procedures, and solving routine problems. The TIMSS videotape classroom study also found an emphasis on routine procedures in U.S. mathematics classes (Stigler et al., undated). Teachers in the current study, however, report no greater emphasis on rote skills, such as memorization, than on conceptual development skills, such as making connections.

It could be that the low emphasis on rote skills reported here reflects teachers' *beliefs* about their instruction (Cohen, 1990). For example, Knapp et al. found that many teachers who were trying to use new instructional practices to improve student understanding "got the words but not the tune," or used new learning activities without understanding or capitalizing on their potential (Knapp et al., 1993: p. 23); and in a study of 25 mathematics teachers professing familiarity with and use of standards-based instructional strategies, only four truly demonstrated the intent of the standards (Spillane & Zeuli, 1999).

The Eisenhower evaluation observations found examples of similar differences between teachers' perceptions of their instruction and observers' analyses of the same classes. An elementary school in Richmond provides an example of the discrepancy between a teacher's description of her instruction and a trained observer's description of the same class. For the first half of this lesson, the teacher led a whole-class review of operations (e.g., addition, subtraction, exponents, square roots). She wrote pieces of equations on the chalkboard and asked students to fill in the missing information. While the lesson allowed students to "create" equations, the thinking tasks were defined within very narrow parameters, and the focus of the lesson was on arriving at the "correct answer." The teacher felt that she was emphasizing complex performance goals such as interpreting data and making connections for more than half of this part of the lesson (66 percent). The two observers, however, saw an emphasis on lower level performance goals, such as performing procedures and memorizing (60 percent).

A middle school in Rhinestone provides an example of a lesson that emphasizes more complex performance goals. In this middle school science lesson, students constructed a bridge out of spaghetti and marshmallows. The bridge had to meet certain specifications of length and width and have certain characteristics (e.g., it had to have two piers). According to the teacher, this project was intended to make more concrete the construction problems students had been discussing in previous classes. The class was part of a larger unit on bridges and other structures, and the unit was part of an inquiry-based curriculum designed by the observed teacher and a peer.

After the class, the teacher and the observer separately identified the performance goals and topics emphasized in the class. Both the teacher and the observer felt the lesson stressed performance goals that had to do with developing complex understanding. The teacher and observer gave favorable descriptions of the class. Both agreed on the percentage of emphasis the lesson gave to memorizing. But the teacher felt that she placed more emphasis on understanding content than the observer thought she did.

Clearly, in some cases, teachers are emphasizing performance goals of increased student understanding. However, in some cases, changes in instruction may not be at the level that would improve student understanding.

These observations raise the question of the prevalence of teacher exaggeration in their reported instruction. Do teachers, in general, tend to over-report performance goals that they see as positive? The second example shows that teachers do not consistently exaggerate. Yet the first example shows that some teachers may report a more favorable picture of their instruction than is observed. Although we cannot conclusively determine the accuracy of teachers' reporting from these data, the self-reporting bias, if any, should not have much influence on the analyses of change in teaching practice to be discussed in our third report, because we would expect any bias to be constant across the three waves of the survey.

As previous research suggests, there may be a gap between the teacher's perception of her instruction and a more objective evaluation of the same lesson. Teachers may believe they are teaching in ways consistent with high standards; without feedback on their instruction, they may not recognize areas for improvement. Well-constructed professional development, which provides opportunities for such feedback, may help teachers continue to evaluate and improve their instruction.

Content Emphases: The Intersection of Topics and Performance Goals

In this section, we turn to the emphasis teachers give to specific content areas—that is, to the intersection of topics and performance goals. As noted above, the idea of "content" includes both the topic of instruction and the teacher's goals for student performance.

The mathematics and science standards present a vision for instruction, in which each grade builds on the learning in the previous grade. However, research on teaching practice and findings reported earlier from the current study suggest that subtopics and performance goals do not become more challenging as students move through the grades. Rather, students visit and revisit the same topics and subtopics at a superficial level. This curriculum organization contributes to a phenomenon in the U.S. recognized as "teaching for exposure" (Porter, 1989). Because many topics and subtopics are taught at more than one grade level, teachers provide very limited instruction in a large number of topics and subtopics. This practice is unlikely to deepen students' understanding of any particular topic (Rollefson, 1996). Effective instruction must balance covering a variety of content areas (breadth) with developing deep understanding in each content area (depth), perhaps even emphasizing depth by limiting breadth somewhat (Raizen, 1998).

To assess the depth and breadth of content covered, we counted the total number of possible content areas (cells) in our matrix. We then determined the percentage of cells that teachers reported covering, and compared this percentage with content areas (cells) assessed by the NAEP. Our results, shown in Exhibit 2.8, indicate that teachers' instruction shows greater breadth than is reported on the NAEP. While the NAEP does not assess and the surveyed teachers do not cover all possible content areas, teachers consistently cover substantially more content areas than represented in the NAEP, in some cases as much as twice as many areas.[13] For example, teachers cover 39 percent of the 144 content areas in middle school science, while the NAEP assesses only 16 percent.[14] Teachers in high-poverty schools tend to cover more content areas than teachers in low-poverty schools.

EXHIBIT 2.8

Comparison of NAEP and Teachers in the Longitudinal Teacher Survey on Coverage of Content Areas (n=355)

	Mathematics			Science		
	Elementary School	**Middle School**	**High School**	**Elementary School**	**Middle School**	**High School**
Number of possible content areas	60	54	96	96	144	168
Percent assessed by NAEP	35%	34%	20%	26%	16%	15%
Percent covered by teachers	47%	51%	43%	36%	39%	32%

Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first column shows that for elementary school mathematics, there are 60 possible content areas. Thirty-five percent of the possible content areas were assessed by NAEP. Forty-seven percent of the content areas are covered by teachers in our sample. Coverage of content areas data are listed in the rows. Grade levels are in the columns. The possible coverage can be between zero and 100 percent.

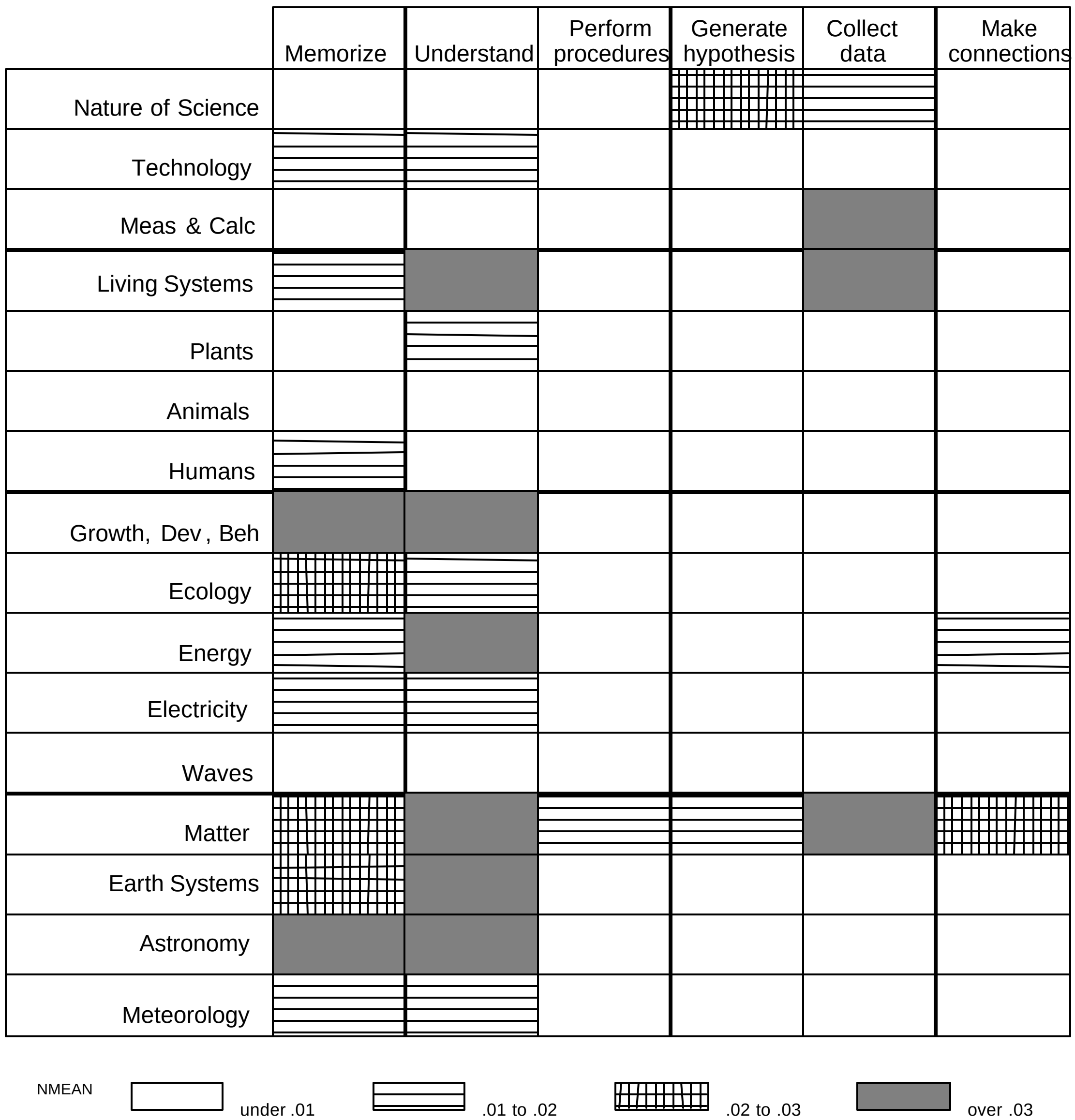
Covering a large number of content areas is not necessarily an instructional liability; however, if by covering more content areas teachers are unable to focus on each content area as thoroughly as needed, students may not have opportunities to develop deep understandings in each area. Our data suggest this is the case. In comparison to the NAEP items, teachers cover more content areas, giving many relatively little emphasis. For example, Exhibit 2.9a shows that in elementary school science, the NAEP gives strong emphasis (greater than 3 percent emphasis) to 11 content areas; Exhibit 2.9b shows that teachers report strong emphasis on only three content areas. On the other hand, the NAEP gives weak emphasis (1 to 2 percent emphasis) to only 15 content areas, shown in Exhibit 2.9a, while teachers report a weak emphasis on 27 areas. This pattern is found across subjects (i.e., mathematics, science) and school levels (i.e., elementary, middle, high school). As previous research suggests, and the current analysis reiterates, teachers tend to favor breadth over depth in their instruction.

[13] Some performance goals that are especially difficult to measure on a timed, paper-and-pencil test, such as generating hypotheses, may be underrepresented on the NAEP.

[14] This difference might be due, in part, to the fact that the teachers reported on *all* content areas covered over the course, while the NAEP only tests on a *sample* of content areas that students are expected to learn. However, the analysis included the full set of NAEP items, which is a sizable sample of items, so NAEP content coverage should be substantial.

EXHIBIT 2.9a

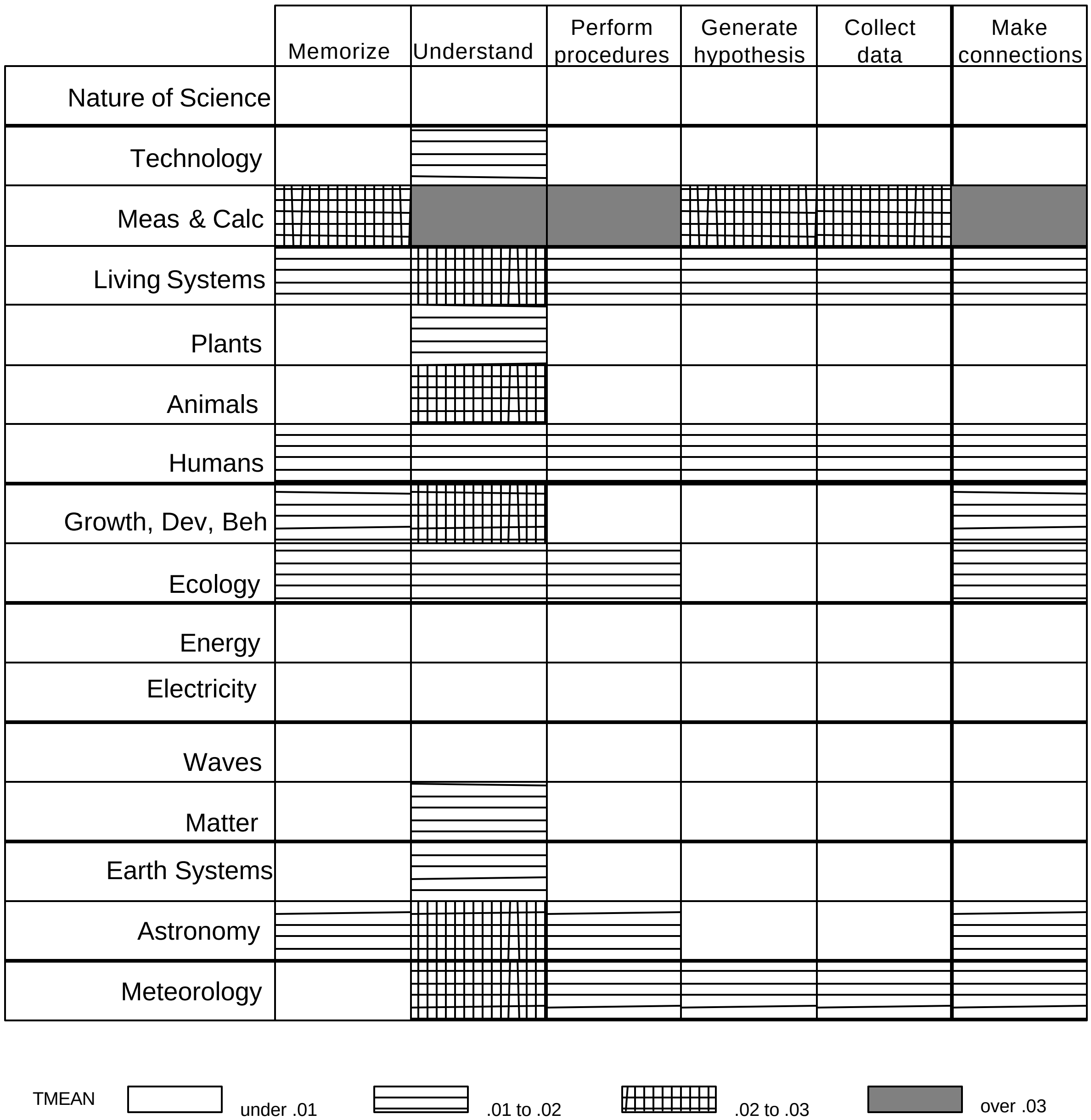
Emphasis on Content Areas in Fourth-Grade Science NAEP Items



Source: NAEP, 1996.
How to read this exhibit: The rows represent topic areas and the columns performance goals. Each cell is a topic area and performance goal combination. Blank boxes indicate less than one percent of relative emphasis for a particular topic and performance goal combination by NAEP. Boxes with horizontal lines indicate between one and two percent of relative emphasis for a topic and performance goal combination by NAEP. Checkered boxes indicate two to three percent of relative emphasis for a topic and performance goal combination by NAEP. Shaded boxes indicate over three percent of relative emphasis for a topic and performance goal combination by NAEP. For the Nature of Science, under one percent of the relative emphasis given by NAEP items was on the performance goal Memorize.

EXHIBIT 2.9b

Emphasis on Science Content Areas, Reported by Elementary School Teachers in the Longitudinal Teacher Survey (n=69)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year). Kindergarten through fifth grade teachers.
How to read this exhibit: The rows represent topic areas and the columns performance goals. Each cell is a topic area and performance goal combination. Blank boxes indicate less than one percent of relative emphasis for a particular topic and performance goal combination by teachers. Boxes with horizontal lines indicate between one and two percent of relative emphasis for a topic and performance goal combination by teachers. Checkered boxes indicate two to three percent of relative emphasis for a topic and performance goal combination by teachers. Shaded boxes indicate over three percent of relative emphasis for a topic and performance goal combination by teachers. For the Nature of Science, under one percent of the relative emphasis given by teachers in the longitudinal teacher survey was on the performance goal Memorize.

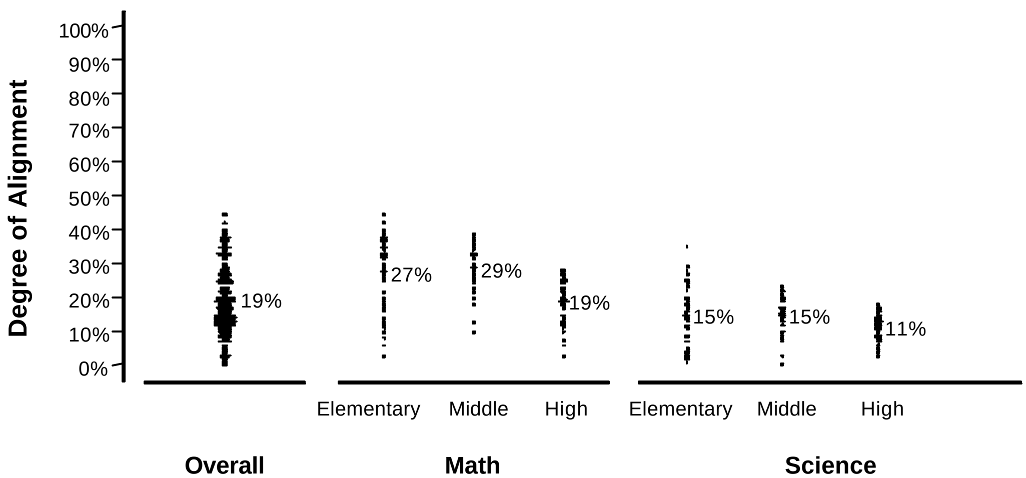
Alignment between Content Emphases and High Standards

Finally, in this section, we report an overall measure of the alignment between the content areas taught by teachers in our sample and the content areas emphasized by the NAEP. We computed the measure based on the relative emphasis given to each content area in our matrix (each cell) by the teachers and by the NAEP.[15] For each teacher, the index takes on a value ranging from zero (no agreement at all between the content areas the teacher emphasizes and those emphasized by the NAEP) to 100 percent alignment (complete agreement between the content areas emphasized by the teacher and the NAEP). High alignment indicates that teachers emphasize topics and performance goals that were similar to NAEP's emphasis. For example, teachers might focus especially on understanding concepts (a performance goal) for motion and forces (a topic) by asking students to explain, in everyday terms, the relationship between motion and force. If the NAEP also emphasizes understanding concepts for motion and forces, there would be high agreement between instruction and the NAEP on that content area. If there were a pattern of such agreement across content areas, then the index of alignment would be high.

Depending on the subject (i.e., mathematics or science) and the school level (i.e., elementary, middle, or high school), the average alignment between the surveyed teachers' instruction and the NAEP ranges from 11 to 29 percent (see Exhibit 2.10). Considering the large number of content areas, alignment of 29 percent is quite high. There is no significant difference in alignment between high- and low-poverty schools.

EXHIBIT 2.10

Degree of Alignment between Teachers' Instructional Emphases and NAEP Emphases (n=355)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first distribution shows that on average teachers' instructional emphases is aligned 19 percent with the NAEP emphases. Each dot represents one teacher in our sample. As the number of teachers at one data point (or value) increases, the dots form a horizontal line that increases in length. Each distribution represents the distribution for that particular category. The number to the right of the distribution is the mean.

[15] The index of alignment is computed as the sum, across content areas, of the absolute value of the difference between the teacher's and the NAEP emphasis in each content area, divided by two, subtracted from one; the result is multiplied by 100. The absolute value is required because the index is designed to capture cells for which the teachers give more emphasis than the NAEP, as well as those for which they give less emphasis.

As can be seen in Exhibit 2.10, the content of instruction for teachers in our sample is better aligned with the NAEP in mathematics than in science. There are a number of possible reasons for this. Mathematics often is seen as a core subject; everyone generally agrees that children should learn fractions or geometry. Science, however, is not always so central to the curriculum, especially in the early grades (Kennedy, 1998; Raizen, 1998). At all levels, students have less exposure to science than to mathematics: 30 minutes per day for science compared to 60 minutes per day for mathematics in elementary schools, and two to three years of mathematics compared to two years of science required in high school (Weiss, 1997). Further, there is greater national consensus on core topics in mathematics than in science: state mathematics curricula tend to focus on common topics, while there is little overlap between states in terms of science emphasized by the state curricula (Schmidt et al., 1996).

Finally, teachers may be less familiar with science, and this could affect the quality of instruction. Elementary school teachers generally have a basic understanding of reading and mathematics, and feel comfortable teaching these subjects; however, they may be less knowledgeable about and comfortable teaching science. Research suggests that teachers' content knowledge affects their instruction (Rollefson, 1996). A survey of elementary school mathematics and science teachers found that 60 percent felt qualified to teach mathematics, 28 percent felt qualified to teach life sciences, and fewer than 10 percent felt qualified to teach physical science (Weiss, 1997). Teachers teaching out-of-field may misrepresent key concepts or focus on trivial rather than central concepts and tend to rely on drill-and-practice activities rather than instruction oriented toward student inquiry. Further, because the science standards are relatively new, teachers and students have had limited time to become familiar with them.

Our data also indicate that content was more highly aligned with the NAEP in the elementary and middle schools than in the high schools. This phenomenon might be an artifact of the test. Although the NAEP is used as a standard for high expectations, the high school test is geared toward content covered prior to high school. Thus, the standard set by the high school NAEP test might not be as challenging as the instruction of teachers who participated in the Eisenhower evaluation. Although most of the high school teachers in the sample described average-level courses, such as algebra and biology, some did describe advanced courses such as calculus and physics, and honors courses (see Appendix D).

Our data indicate that the degree of alignment of the content taught with high standards seems to be related to the school in which instruction occurs. As much as 30 percent of the difference among surveyed teachers in terms of how well their instruction meets high standards can be attributed to the school in which the teacher teaches (see Appendix D). Our data indicate that the effect of the school on alignment with the NAEP is greater for science than for mathematics instruction, and greater for elementary and middle schools than high schools. These findings imply that, at least for this sample, strategies to help teachers improve instruction should be targeted to schools.

Finally, although we talk about average alignment across groups of teachers, teachers differ from each other in how closely their instruction aligns with the NAEP. This variation is quite visible in Exhibit 2.10, which shows that some teachers are nearly 50 percent aligned with the NAEP, while others have almost no alignment. For example, the instruction of one elementary school science teacher (called Teacher A) was minimally aligned with the NAEP: on an index of zero to 100, with 100 indicating perfect alignment, she had alignment of less than one percent. On the other hand, the instruction of another elementary school science teacher (called Teacher B) was relatively highly aligned with the NAEP: in the alignment index, she had alignment of 35 percent. The performance goals and topics that Teacher B emphasized resembled the NAEP much more closely than the performance goals and topics of Teacher A. Teacher B stressed memorizing and understanding, as the NAEP does, while Teacher A stressed performing procedures and collecting/analyzing/ interpreting data, unlike the NAEP. Teacher B emphasized components of living systems, ecology, properties of matter, and astronomy similarly to the NAEP, while Teacher A emphasized maintenance in animals, unlike the NAEP. A teacher such as Teacher B, whose instruction already meets high standards, may not need the same type of guidance as a teacher such as Teacher A, whose instruction is weak compared to the standards.

Summary: Content Coverage and High Standards

Data from the baseline Longitudinal Teacher Survey indicate that the content taught by teachers in our sample is moving toward but does not yet meet high national standards in several ways. Teachers do not focus on some advanced topics; rather, they emphasize low-level topics. Although teachers set more complex performance goals for their students than they have historically, the changes in their instruction are not always as deep as the teachers perceive them to be. Teachers appear to teach for exposure, and the content covered does not appear to become substantially more challenging in successive grades. These findings are generally consistent with previous research, which suggests that instruction in American schools does not emphasize challenging content.

Targeted professional development can help address these concerns. For example, professional development that focuses on content can help teachers develop a deeper understanding of the content they teach and develop lessons that are rich in challenging content (Kennedy, 1998). Professional development with in-classroom follow-up components could help teachers understand the level at which their instruction has changed and the areas in which the intended change is still superficial. (See, for example, Schifter, 1996). School-based professional development that includes the collective participation of groups of teachers from the same grade could help teachers organize instructional emphases across grades, so that each successive grade builds on the previous one. Later chapters examine the prevalence of these types of designs and characteristics in Eisenhower-assisted professional development activities and their relationship to teacher outcomes.

PEDAGOGY AND HIGH STANDARDS

Section Findings

- *Science teachers, elementary school teachers, and teachers in low-poverty schools report using more nontraditional pedagogy compared to mathematics teachers, middle and high school teachers, and teachers in high-poverty schools.*

- *Teachers who emphasize concrete performance goals for their students, such as memorizing, tend to report using traditional, teacher-centered pedagogy. Teachers who give more emphasis to abstract performance goals for their students, such as understanding concepts, tend to report using active, project-centered pedagogy.*

To this point, we have focused on the content of instruction: the topics and performance goals that teachers emphasize, and how they compare to high standards for content. However, the delivery of instruction—the pedagogy—also is important to effective teaching. Students learn best when they are actively involved in learning, when assessment tools are used to tailor the lesson to the students' individual needs, and when students have access to a variety of tools and modes for learning. However, according to the literature, traditional instruction tends to be led by the teacher and de-emphasizes student-initiated activities other than highly structured individual seatwork (for example, completing exercises in a text or on worksheets) (Gamoran, Secada, & Marrett, 1998). Traditional instruction entails at least two dimensions: an emphasis on teacher presentation and highly structured lessons using traditional materials (e.g., texts). Conversely, nontraditional instruction revolves around student-initiated activities, including projects and discussion, and the use of innovative materials (e.g., manipulatives). Research suggests that teachers are beginning to explore nontraditional pedagogy, and to use a mix of traditional and nontraditional pedagogy in their instructional practice (Spillane & Zeuli, 1999).

In this section of the chapter, we describe and analyze the pedagogical approaches of teachers in our sample. We conducted analyses on a series of six questions in the Longitudinal Survey about teachers' pedagogical strategies. Based on these analyses, we first describe these teachers' classes: the average percent of time teachers and students spend in various types of activities, the average relative emphasis on different types of tasks and grouping of students. Next, we identify pedagogical patterns in the class activities, such as didactic instruction or active, project-centered instruction. We look at patterns within our sample, for example identifying where elementary, middle, and high school teachers differ in their pedagogical approaches. (See Appendix D for details on analysis methods.) Finally, we look at the relationship between pedagogy and content, in order to establish empirically whether certain pedagogical approaches are more consistent with high standards for content than others.

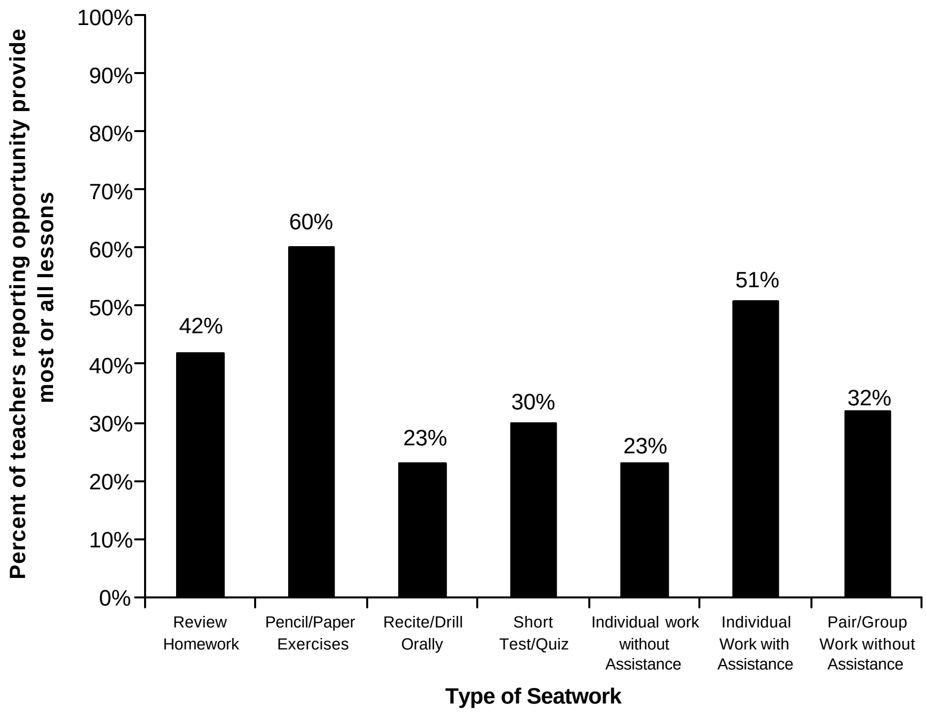
Class Activities

Class activities provide a picture of students' learning experiences. To some degree, the emphasis on some types of activities can show how consistently teachers are using the types of activities advocated by the research.

The teachers in this study spent one-third of their instructional time on teacher-led activities such as lecturing or providing demonstrations, and two-thirds of their instructional time on activities that could actively involve students, such as whole class discussions, small group and individual work, and hands-on experiences. Exhibit 2.11a shows that a high percentage of teachers (23 to 60 percent) have students do traditional activities, such as working on homework, pencil-and-paper exercises, and taking quizzes, in most or all lessons. Exhibit 2.11b shows that a lower percentage of teachers (12 to 31 percent) have students work on nontraditional activities, such as independent long-term projects or problems for which there is not an immediate solution, for most or all lessons.

EXHIBIT 2.11a

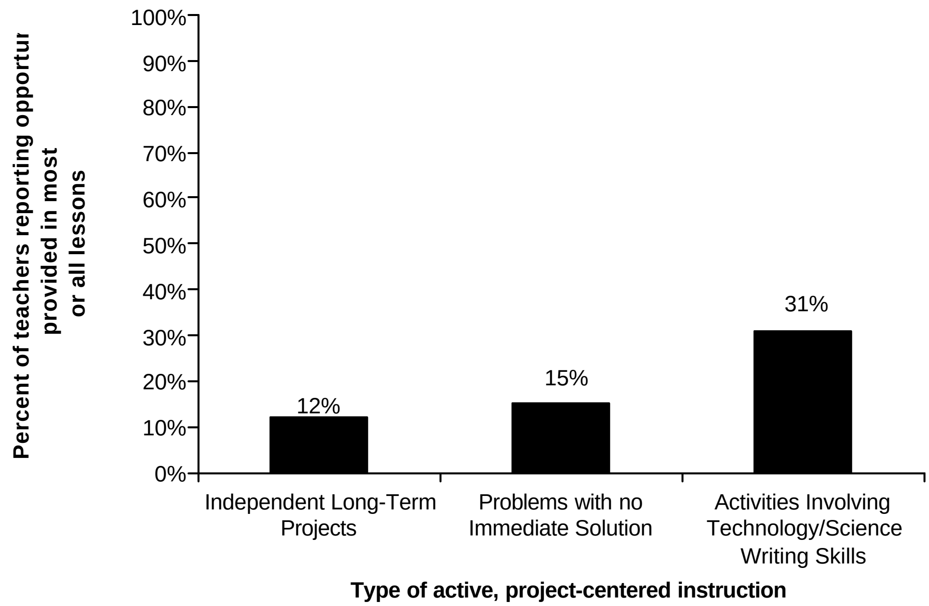
Percent of Teachers Using Traditional Activities in Most or All Lessons (n=355)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first bar shows that percent of teachers report using in most or all lessons. Each bar and the number on top of it represent the percent of teachers who report using that activity in most or all lessons.

EXHIBIT 2.11b

Percent of Teachers Using Nontraditional Activities in Most or All Lessons (n=355)



Source: Longitudinal Teacher Survey, Fall 1997 (1996-97 school year).
How to read this exhibit: The first bar shows that percent of teachers report using in most or all lessons. Each bar and the number on top of it represent the percent of teachers who report using that activity in most or all lessons.

Pedagogical Patterns

Research suggests that teachers tend to favor particular approaches to pedagogy, with certain types of class activities occurring together (Peterson, Fennema, Carpenter, & Loef, 1989; Stein, Baxter, & Leinhardt, 1990). While professional development can focus on changing individual classroom activities, such as seatwork, professional development is more likely to have a lasting impact if it targets the teacher's broader pedagogical approach (Hyde, Ormiston, & Hyde, 1994). Therefore, in this section, we identify general pedagogical approaches that represent the ways teachers organize classroom practices.

We conducted a factor analysis on the survey questions noted above to identify pedagogical patterns in instructional activities. Consistent with the research on pedagogy, we found four distinct patterns of activities.

We developed a set of four scales to measure the extent to which teachers rely on these four pedagogical strategies. Each scale is scored to have a mean of 50 for the teachers in our sample. Two measures capture traditional strategies:[16]

1. Didactic instruction: Didactic, or teacher-led, instruction includes the following activities: lecturing and having students take a passive role; de-emphasizing group work, reading, writing, and student presentations; and not using concrete models or interdisciplinary lessons.

2. Individual seatwork: Individual seatwork includes the following activities: working on homework in class, working on pencil/paper exercises, reciting or drilling orally, taking quizzes, and having students work individually, or in pairs.

Two measures capture nontraditional strategies:

1. Active, project-centered instruction: This factor includes the following activities: students working on independent, long-term projects, problems with no immediate solution, and technical writing skills; using hands-on activities; de-emphasizing paperwork and individual work.

2. Discussion-oriented instruction: This measure focuses on discussion only.

The pedagogical approaches we identified here are consistent with the research on pedagogy, giving us confidence that the pedagogy of the teachers in this sample is fairly representative. The national standards, as well as research on pedagogy, indicate that effective instruction calls for an increased emphasis on nontraditional pedagogical approaches, without fully abandoning traditional approaches. The degree to which individual teachers emphasize those pedagogical approaches is one indicator of their consistency with national standards.

Pedagogical Patterns within the Sample

According to the research, pedagogy differs substantially by type of school and subject. For example, high schools tend to have more highly structured lessons, with greater emphasis on individual work, compared to elementary schools. However, national mathematics and science standards consistently emphasize active instruction for all students, regardless of school level, school poverty, or subject. Therefore, it is useful to understand how subgroups of schools and students differ in their use of effective pedagogy. To examine these questions, mean scores were computed on the four pedagogy scales by school level (elementary, middle, and high school), subject (mathematics and science), and poverty level (high and low).

We found some differences among types of teachers and types of schools in the pedagogy favored, as shown in Exhibit 2.12. Mathematics teachers are significantly more likely to use seatwork (traditional) and science teachers are significantly more likely to use active instruction (non-

[16] We also explored a measure of technology use (e.g., computers and calculators), because previous research suggests that teachers traditionally use technology for drill and practice on facts and skills, but that they may be learning to use technology for more advanced learning goals. However, responses to the technology questions seemed to reflect resources (e.g., greater or lesser access to technology) rather than pedagogy (e.g., how technology is used in the classroom). Therefore, it was not appropriate to discuss the technology factor in this section.

traditional); this is consistent with findings from the observed sites, where mathematics lessons sometimes revolved around textbook work and science lessons often involved labs. Compared to elementary school teachers, high school teachers use more didactic instruction and individual seatwork (traditional), and less discussion-oriented instruction (nontraditional). Low-poverty schools are significantly more likely to use didactic instruction (traditional) than high-poverty schools; otherwise, there is no significant difference between high- and low-poverty schools in types of pedagogy used.

EXHIBIT 2.12

Mean Teacher Use of Four Pedagogical Approaches (Standard Deviation), by School Level, Subject, and Poverty Level (n=355)

	Traditional		Nontraditional	
	Teacher-Centered	**Individual Seatwork**	**Active**	**Discussion – Oriented+**
School Level				
Elementary	47.13 (5.30)	49.09 (5.92)	50.36 (4.72)	51.38 (8.06)
Middle	50.47 (6.10)	49.41 (5.96)	49.88 (7.95)	50.16 (8.00)
High	53.33 (5.51)	51.33 (5.67)	49.62 (5.65)	48.30 (9.07)
Subject				
Mathematics	50.53 (6.23)	51.66 (5.34)	47.93 (5.70)	50.23 (19.11)
Science	49.85 (6.14)	48.27 (6.00)	52.11 (5.34)	49.66 (8.35)
Poverty Level				
High Poverty	48.46 (6.03)	49.98 (6.24)	49.93 (6.36)	50.60 (8.47)
Low Poverty	51.20 (6.08)	49.96 (5.64)	50.00 (5.66)	49.59 (8.91)

+ n=342

Source: Longitudinal Teacher Survey, Spring 1998.
How to read this exhibit: The group of three cells at the upper left of the table (scale score means for teacher-centered instruction by school level) shows that high school teachers use significantly more teacher-centered instruction than middle school teachers and elementary school teachers, and middle school teachers use significantly more teacher-centered instruction than elementary school teachers. The table should be read by columns, focusing on each pedagogical strategy separately.
Note: Results in table are scale scores, with a mean of 50 for the teachers in the sample. The arrows indicate significant differences between groups (p<.05), with the head of the arrow showing the direction of the difference.

The Relationship between Pedagogy and Content

Both pedagogy and content are critical for successful instruction, and teachers who tend to have high standards for one also have high standards for the other. In this section, we examine the relationship between teachers' pedagogical approaches and the content of their instruction to determine empirically whether certain pedagogical approaches are consistent with high standards for content. We explore this premise by correlating teachers' pedagogical approaches with the content of their instruction. Teachers whose instruction is well-aligned with NAEP tend to emphasize seatwork and discussion, and de-emphasize active, project-centered instruction (see Exhibit 2.12).

We also focused on one of the two components of content: teachers' performance goals for students (see Exhibit 2.13). It may be that teachers expect a certain level of performance from their students, emphasizing more concrete or more abstract performance goals, and that they choose pedagogical approaches to help their students reach those types of performance goals. We examined the relationship between teachers' performance goals for students and the pedagogical approaches they favor. We found that traditional, didactic instruction emphasizes the more concrete performance goals, such as memorizing and performing procedures, and de-emphasizes performance goals that involve abstract thinking, such as generating hypotheses, collecting/analyzing/interpreting data, and making connections.[17]

EXHIBIT 2.13

Correlations between Pedagogical Approaches and Elements of Content (n=355)

	Didactic	Individual Seatwork	Active, Project-Centered	Discussion-Oriented+
Alignment with NAEP Items				
Index of Alignment	ns	.22***	-.14**	.13*
Performance Goals				
Memorize	.22***	ns	-.22***	ns
Understand Concepts	.18***	-.21***	ns	ns
Perform Procedures	.12*	.15**	-.26***	ns
Generate Hypotheses	-.25***	.13*	.25***	ns
Collect/Analyze/ Interpret Data	-.24***	ns	.28***	ns
Make Connections	-.21***	ns	.19***	ns

+ n=342
* statistically significant at p<.05
** statistically significant at p<.01
*** statistically significant at p<.001
ns not statistically significant

Source: Longitudinal Teacher Survey, Spring 1998.
How to read this exhibit: The first cell shows that didactic pedagogy is significantly correlated with the performance goal of memorizing; in other words, the more that teachers emphasize memorizing, the more that they present or lecture. The table should be read by columns, focusing on each pedagogical strategy separately.

Nontraditional, active instruction, on the other hand, emphasizes complex performance goals including generating hypotheses, collecting/analyzing/interpreting data, and making connections, and de-emphasizes more concrete performance goals, including memorizing and performing procedures. In other words, teachers who would like their students to develop more concrete performance goals,

[17] Contrary to expectations, the performance goal of students' understanding concepts is related to traditional instruction. It may be that teachers see this performance goal as concrete (e.g., students can recite a research theory) rather than abstract (e.g., students can explain a research theory).

such as memorizing, tend to use traditional, didactic pedagogy and teachers who would like their students to develop abstract performance goals, such as making connections, tend to use active, project-centered pedagogy. This finding is consistent with the literature on pedagogy, as well as national pedagogical standards for mathematics and science, which advocate using active instruction to help students develop complex thinking skills.

Summary: Pedagogy and High Standards

Traditional and nontraditional teaching strategies can be, and are, part of instruction that meets high standards. Some teachers incorporate seatwork with discussion, and the results indicate that both seatwork and discussion are related to high content standards. Some, but not all, teachers incorporate nontraditional pedagogy that actively involves students into their teaching. Professional development can play a key role in helping teachers learn to integrate traditional and nontraditional teaching strategies, and help them improve the quality of student-centered instruction. For example, in-class observations and feedback, following professional development experiences, can help teachers understand whether they are using the tools of active instruction on a superficial level (e.g., discussions that are geared to identifying the "correct" answer) or pushing students toward more complex understanding (e.g., discussions that encourage students to surface underlying concepts). Later chapters in this report will examine the extent to which Eisenhower-assisted activities offer active learning opportunities, as well as other characteristics of high-quality professional development. We also will examine how the design and characteristics of Eisenhower-assisted activities are related to teacher outcomes.

SUMMARY AND CONCLUSIONS

In this chapter, we have established a baseline understanding of the approaches to instruction reported by teachers in the Longitudinal Study of Teacher Change. By comparing the content covered by teachers in the sample with content included in NAEP items, critical areas have been identified where professional development could contribute to teaching practice.

In addition, we have examined the degree to which teachers in the sample rely on traditional and non-traditional pedagogical methods. Prior research indicates that at least two elements of instruction matter for student learning: content that is aligned with high standards and pedagogy emphasizing active learning. The sampled teachers are working toward both elements of effective instruction, but are not there yet.